A Pedal Powered Water Purifier

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Abstract

Water is a necessity for every living organism on Earth. However, in certain parts of the world especially in rural areas, clean drinking water is a luxury to the residents. This is because they are not supplied with clean water and thus must source for water from rivers, rainwater, and wells which are often contaminated and unsafe for drinking. The objective of this study is to design and fabricate a functional prototype of a pedal powered water purifier, and to ensure that purified water is safe for consumption based on chemical water analysis. The quality of the purified water will be compared to the Drinking Water Guidelines provided by the World Health Organization (WHO). The system utilizes the distillation method to produce clean drinking water. The charging efficiency of the generator has reached 48.74% at 60rpm cadence. Based on the chemical analysis of purified water, it has been proven that it meets the standards set by WHO and is safe for consumption.

Keywords: Distillation; Energy Conversion; Drinking Water, Renewable Energy Generation.

1. Introduction

Clean water supply is often unavailable in certain rural areas. This poses a huge challenge to the people living in rural areas, as they would have to obtain water from rivers or rainwater. These water sources are often polluted due to human activities such as open burning, improper disposal of garbage and industrial waste. If the water is not treated properly before consumption, the consumers are in high risk of being infected by diseases or poisoned.

There are several methods to purify water such as boiling, distilling and reverse osmosis. However, distillation is one of the most reliable methods of water purification [1]. The distillation process is able remove contaminants such as microorganisms, dissolved substances, and suspended substances, thus resulting in a very pure water. To verify if the purified water is safe for consumption, it is necessary to conduct chemical water analysis on the purified water, and then comparing the results to the World Health Organization (WHO) Drinking Water Guideline. The parameters to be measured as indicated in the drinking water guideline are chemical properties, bacteriological properties and physical properties of the water [2].

Distillation is a process which consists of evaporation and condensation. Heat energy is required in distillation to allow the water to evaporate. Traditionally, heat is obtained by combustion of fuel, which is harmful to the environment as it produces greenhouse gases that contributes to global warming. Therefore, electrical energy is a better alternative to produce heat energy. Electricity can be generated in several methods. Pedal power generation is the method used in this research that works on the principle of conservation of energy, as kinetic energy from pedalling motion is converted into electrical energy. According to researchers, they have found that the most efficient cadence is 60 rpm as it has the lowest metabolic cost [3]. Functional threshold power (FTP) is the maximum average power a cyclist can sustain within one-hour period. Experiments have been done and it shows that average cyclists have an average FTP of 210.6W [4]. In addition, there are torque variations of over 90% and speed variations of about 5% in a single crank revolution [5]. These data are crucial while designing a pedal powered generator.

2. Overview of System

The proposed system is to work on the principle of conservation of energy, whereby energy is converted from one form to another. The basic working principle of the system is shown in Fig. 1. When the user pedals, the kinetic energy is transferred from the crank to the chain, and then to the sprocket of the generator. Then, mechanical energy produced by pedalling is converted to electrical energy with the generator, and the electrical energy will be stored in a battery. The electrical energy stored will then be used as per the need of the user to operate a water heating element for water heating and distillation. During the distillation process, the water will first be boiled, and the steam produced will be channelled through a copper tube to allow for condensation. Finally, pure water will be produced from the condensed water.

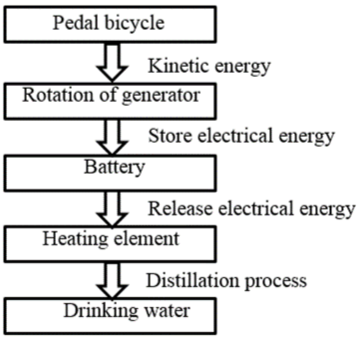

Fig. 1. Flow chart of working principle of system.

3. Fabricated Prototype

A prototype has been fabricated to conduct the experiments, and the components of the prototype are labelled in Fig. 2. and listed in Table 1.

Fig. 2. Full components of prototype.

Table 1. List of prototype components

No.	Component	Specifications
1	Bicycle	N/A
2	Supporting frame	N/A
3	Generator	36V, 250W, 3000rpm
4	Multimeter	N/A
5	Battery	12V, 8Ah
6	Charge controller	12V DC to 36V DC
7	Heating container	N/A
8	Cooling container	N/A
9	Collection container	N/A

In the distillation unit, a heating container, cooling container and collection container are shown in Fig. 3. In the heating container, a heater is immersed to boil and evaporate the water. Then, the steam will pass through a copper tube having a water jacket to allow for a higher condensation rate. The condensed steam is converted now to pure water.

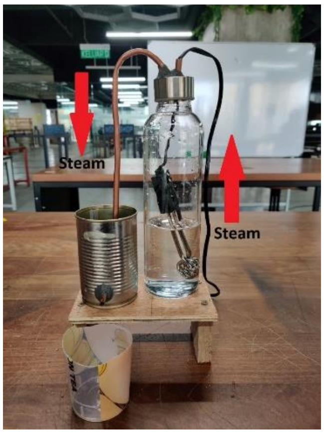

Fig. 3. Distillation unit.

3.1. ***Energy analysis***

The system has been tested to verify the efficiency of the generator. The equipment used in the test are Garmin Edge 1030, Garmin Heart Rate Monitor and Garmin Cadence Sensor to determine the RPM of the crank and heart rate of the user. The data collected by the sensors are used by the bike computer. Garmin Edge 1030 has been used to calculate the energy exerted according to the manufacturer's algorithm. A multimeter has been used to measure the current and voltage output from the generator. The energy output over the duration of the tests have been measured by the multimeter. The tests have been conducted for 10 minutes duration for each of the RPM at crank. The data recorded is shown in Table 2.

The generator used is having an internal gearbox with a gear ratio of 9.78:1, and the gear ratio of the generator's sprocket with the crank gear is 5.33:1. Therefore, the rotational speed of generator has been calculated with Eq. (1). Whereby N_{gen} is the rotational speed of generator, N_{pedal} is the rotational speed of pedal or cadence.

$$N_{gen} = N_{pedal} \times 5.33 \times 9.78 \tag{1}$$

Based on the data collected, the relation between cadence and efficiency of the generator is plotted and illustrated in Fig. 4. Also, the relation between cadence and voltage is illustrated in Fig. 5, and the relation between cadence and current is illustrated in Fig. 6.

According to Fig. 4, it is shown that the relationship between cadence and efficiency of generator is linearly proportional from 30 rpm until 60 rpm. This is because the selected generator has a rated peak output at 3000 rpm. Therefore, as the cadence reaches 60 rpm, the generator will be rotating at 3129.6 rpm. Furthermore, it also corresponds to the research done by Brennan et.al [3], whereby the cadence of highest efficiency is at 60 rpm.

At 70 rpm, the efficiency drops as compared to 60 rpm. This is because the metabolic cost to maintain cadence at 70 rpm is higher, therefore consuming more energy from the user.

Fig. 5. and Fig. 6. are showing that as the cadence increase, the voltage and current output increase. This characteristic is expected as permanent magnet DC generators are supposed to have a linear relationship between revolution speed and current, and linear relationship between revolution speed and voltage [7].

Table 2. Data collected during efficiency test of generator.

N_{pedal} (rpm)	N_{gen} (rpm)	Current (A)	Voltage (V)	Energy Output (Wh)	Energy Input (kcal)	Energy Input (Wh)	Efficiency (%)
30	1563.82	3.62	12.83	36.00	93.00	108.09	33.31
40	2085.10	4.88	12.90	49.70	107.00	124.36	39.96
50	2606.37	6.91	13.07	74.40	119.00	170.49	43.64
60	3127.64	7.84	13.22	89.50	158.00	183.63	48.74
70	3648.92	8.32	13.36	95.80	179.00	208.04	46.05

The range of calculated efficiency for the generator is ranging from 33.31% to 46.05%. The used battery of 8 Ah capacity could be fully charged in around 57 minutes with charging current of 8.32 A. The fully charged battery can support the system for around 46 minutes, and to boil 2.265 Litres of water and make it ready for drinking.

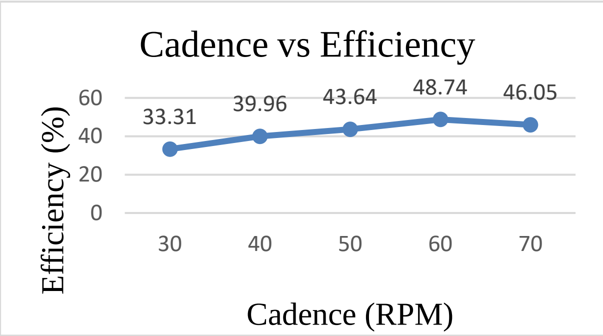

Fig. 4. Relationship between cadence and efficiency of generator.

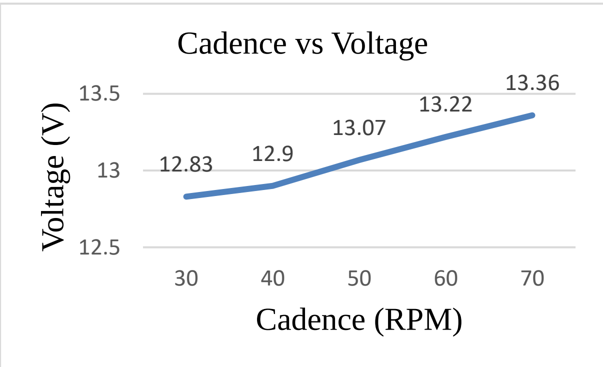

Fig. 5. Relationship between cadence and voltage.

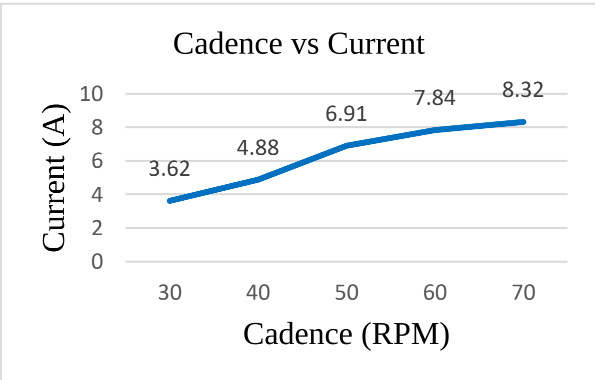

Fig. 6. Relationship between cadence and current.

3.2. *Efficiency Comparison*

The efficiency of the system fabricated in the current study has been compared to the references to verify the results obtained. The efficiency comparison is shown in Fig. 7. The efficiency calculated for the current system is 48.74% , whether the system studied by Anyanwu [8] has higher efficiency and this can be attributed to the lesser electrical losses as it has lesser electrical components. For instance, a charge controller has been used in the prototype of the current study to regulate the voltage input into the battery. The charge controller has to step down the generator output voltage from 36V to 24V as required by the battery for charging. In comparison, a 24V generator has been used in Anyanwu's system and the voltage is not regulated. In the process of stepping down the voltage, some of the electrical energy is wasted as heat energy released into the surrounding, resulting in lower overall efficiency.

The efficiency of the system produced by Zaman [9], is also higher than the current system. The system developed by Goguely [10] has a lower efficiency compared to the current study. It uses a belt drive to transmit force from the rear wheel of the bicycle to the generator. In this case, the slippage is higher as compared to the chain drive utilized in the current system. Furthermore, an automotive alternator has been utilized, which is separately excited and draws power from the battery to produce electromagnetic field. On the other hand, this study has used a permanent magnet generator, which is self-excited and does not require an external power source for field excitation, thus the higher efficiency.

In conclusion, the results that has been obtained in this study can be considered valid in comparison with the other studies.

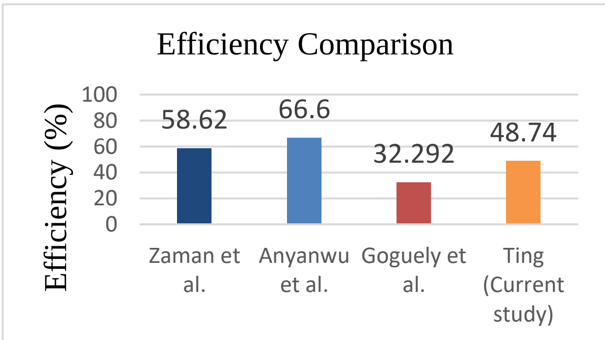

Fig. 7. Efficiency comparison of author to references

3.3. *Water Analysis*

The samples that have been used in this experiment is rain water, stream water, tap water and saline water. The rainwater and tap water have been self-collected at a residential area in Kuala Lumpur, Malaysia. The stream water has been collected from a country side located in Negeri Sembilan, Malaysia. The saline water has been self-made by adding salt to tap water. The content of water before and after purification is shown in Table 3. Based on the results obtained in Table 3, The TDS and EC of each purified samples are different from each other. of WHO Drinking Water Standards. Therefore, the purified water is safe for drinking purposes.

Table 3. Contents of water before and after purification.

Parameters	Source of water								WHO Standards
	Rain water		Stream water		Tap water		Saline water		
	Before	After	Before	After	Before	After	Before	After	
TDS (ppm)	66	15	32	10	63	13	5130	32	1500
EC (μS/cm)	132	46	64	21	126	38	10260	68	2500
pH	7.17	7.09	7.65	7.16	7.34	7.12	8.83	7.20	6.5-8.5

4. Conclusion

The objective of the study has been achieved, which is the design and fabrication of the pedal powered water purifier which has been successfully fabricated and tested. By comparing the results obtained with the references, the efficiency of the generator has been calculated and found that it can reach 48.74% with 60 rpm of the crank. The other achieved objective is ensuring that the purified water is safe for human consumption, as chemical water analysis are conducted. According to the results obtained from the water analysis, all the parameters tested are within the requirement of WHO Drinking Water Guidelines. Therefore, the produced water is safe for human consumption. This is because they are taken from different sources and thus have different level of contamination initially. It can be observed that the TDS and EC are reduced for all the samples, which means that the contaminants in the water have been removed. In addition, the pH level of all the samples is closer to pH 7, which indicates a purer water. It is shown that all 4 samples of water after purification meets the requirement

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5. References

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Authors Introduction

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